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GLACIAL EROSION IN LONGITUDINAL VALLEYS

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The recent papers of Professor Sardeson¹ and Mr. Campbell² on folds in surface strata, the former within and the latter without the glaciated region, suggest the publishing of some analogous observations made in Owasco Lake (New York) valley.

Two questions will be considered in this paper: (1) Did overriding ice produce the folds, and, (2) if so, what bearing does this disturbance of subjacent strata have in the question of glacial erosion? The localities concerned are shown in Fig. 1, which is a transfer of a portion of the Moravia Quadrangle, omitting the 20-foot contour intervals. Owasco Lake lacks one-fourth of a mile of reaching the northern margin of this sheet. Its former higher levels extended several miles southward, as described in the papers of Watson³ and Fairchild,⁴ these higher levels being marked by numerous deltas. Southward from Locke the valley branches about a salient which reaches an altitude of 1,500 feet. The inlet stream rises some thirteen miles south of the present lake in an outwash plain near Freeville. The rock topography suggests a former divide between Locke and Groton.

DESCRIPTION OF THE FOLDS

The overturned fold shown in Fig. 2 is located on the map, Fig. 1, by station 2, northeast of Locke. The cross-section of the fold is nearly perpendicular and is oriented S. 30° E.; its axis has a tilt of approximately 51°. The disturbed layers are fourteen inches thick, consisting of thin, sandy shale, very much disintegrated. These layers overlie a sandstone bed six inches thick, below which are heavier layers used for building-stone. The disturbed strata are

¹ *Journal of Geology*, Vol. XIV (1906), pp. 226-32.

² *Ibid.*, Vol. XIV (1906), pp. 718-21.

³ *N. Y. State Museum, 51st Ann. Rep.*, Vol. I (1897), pp. 792-94.

⁴ *Bull. Geol. Soc. Am.*, Vol. X (1899), pp. 49, 50.

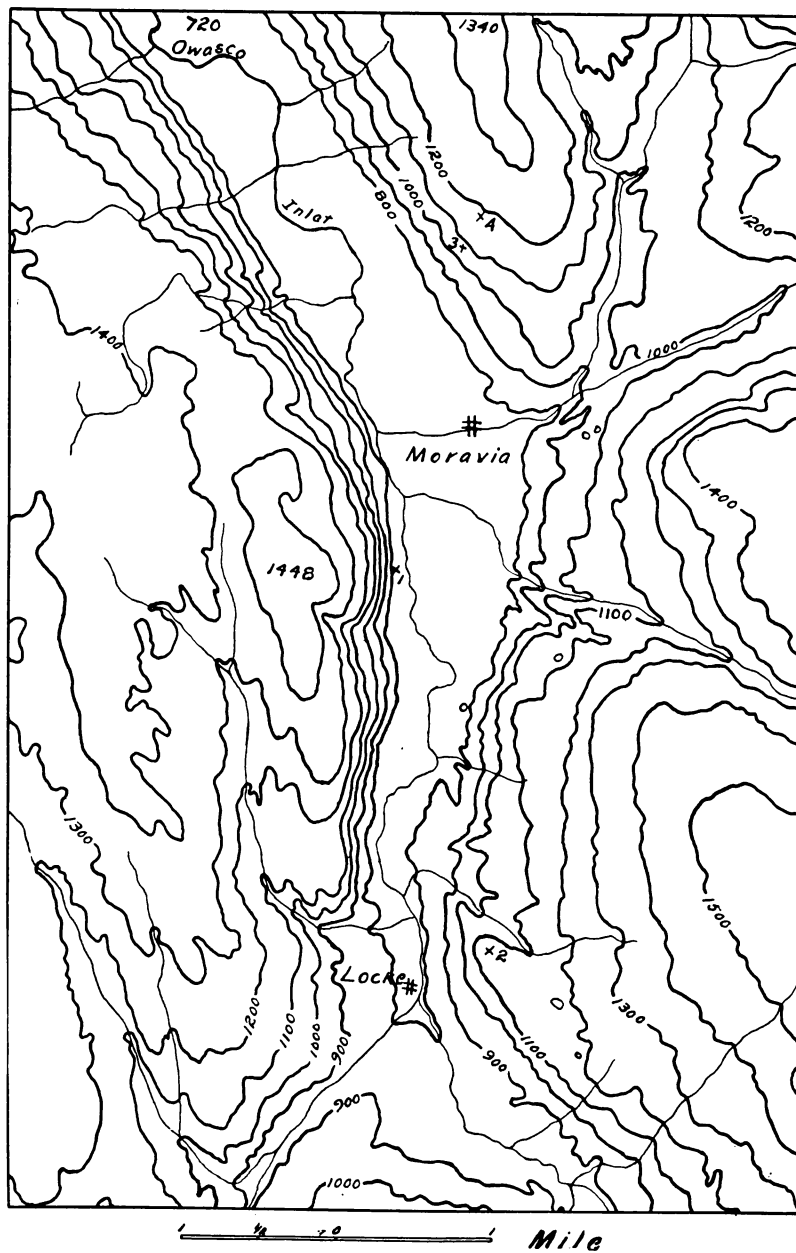


FIG. 1.—Part of Moravia Quadrangle, New York. Contour interval, 100 feet.

overlain by about two feet of drift and rubble, but this horizon very likely consisted formerly of ground moraine which was removed in the process of quarrying.

Fig. 3 is of a fold at station 3, directly north of Moravia. This photograph was taken a few days after an unusually heavy storm which caused many slight streams to leave their former courses, thus exposing fresh sections in the tile. The area shown is on the north side of such a recent cut. The axis of the fold inclines 36° , the section being approximately east-west. The fold is turned up the slope or against gravity; it consists of thin bedded shale and sandy layers amounting to about 18 inches. This is overlain by three to four feet of ground moraine, very compact, and is underlain by a hard layer of sandstone over which the stream is flowing.

HOW THESE FOLDS WERE PRODUCED

As to the causes that may have produced these folds shown in Figs. 2 and 3, which have been selected from a series of photographs of which these are typical: Does the frost theory explain this work? The probable type of a fold caused by freezing is more symmetrical, and, as shown by Sardeson, has in its upper horizon a weathered zone in which the rock has more thoroughly disintegrated, the section blending into less residual material. Fig. 3, however, is obviously below the normal frost line for this climate; while Fig. 2 doubtless shows an area that is subject to frost, as the upper part of the apex of the fold in Fig. 2 very likely has been slightly altered through the influence of frost work. In any event, however, frost folds would be more symmetrical than these. Consequently the frost theory does not seem to apply.

Little need be said concerning the theory of creep, since Fig. 3 is obviously a fold tilted against gravity, while Fig. 2 is a fold along the contour of the slope. It does not seem probable in any event that a fold due to creep would ever be overturned as Fig. 2 is.

Elsewhere in the Moravia Quadrangle folds possibly due to buckling induced by the removal of overlying strata have been observed, but these cases are always symmetrical in relation to the axis of the fold, and apparently show the effects of rather speedy giving away to certain stresses. The agent probably involved in the

removal of the overlying formations is ice, but on this heading too little field work has been done to warrant any definite conclusions. As to the folds in question, it is obvious that they are not due to buckling.

Mr. Campbell establishes the competency of joint expansion due to weathering to produce folds in certain strata. His figures and



FIG. 2.—Subjacent strata folded by glacier ice. Area shown is northeast of Locke, N. Y.

explanation impress the symmetry of such folds. For this reason the theory of weathering cannot apply to our cases.

There are several reasons that point to glacial ice as the agent involved in the present folding. In Fig. 2 the fold is overturned in the direction of ice-motion. This fold lies slightly off the line of the valley segment north of Moravia. Striae to the north and east of the fold, within a radius of one and one-half miles, give an average direction of S. 31° E.,¹ the extremes being S. 18° , and 48° E. Owing

¹ Only magnetic readings are given in this paper.

to the fact that but one section of this fold is exposed there is a possibility of some error in stating exactly the direction of the fold, but from careful study on the ground it seemed plausible that the plain shown in the view is parallel to the direction of ice-motion. If this fold were due to deep-seated stresses, the underlying formations would have suffered disturbance obviously, and since the fold is an over-



FIG. 3.—Subjacent strata folded by glacier ice. Area shown is north of Moravia, N. Y.

turned anticline it seems impossible that any cause of this nature could have become operative without deforming the sandstone beneath.

It is seen that Fig. 3 likewise shows the influence of ice-movements, but not the same type of ice-motion involved in the former case. The topographic map shows a considerable width of valley north of Moravia, a valley which flares northward opening on a fairly level plain within twelve miles. This position favored the expansion toward Moravia of a lobe of ice which had both linear and outward motions. The lateral flow of this tongue obviously produced the fold in question. Some six or seven other instances of similar folds were

noted along the slope within a mile and a half north of Moravia. Some of these were less distorted than the one shown in Fig. 3, one being fairly symmetrical, and possibly to be explained by buckling, since it is several feet below the reach of frost work. But in each case where the axis of the fold was inclined the inclination was up the slope.

It is felt, therefore, that we are dealing with the work of ice in deforming subjacent strata; we have selected cases to illustrate the work of this ice along two lines, one connected probably with the general movement of the ice sheet, or at least the linear movement of a strong valley lobe, the other connected with the outward spreading of a valley lobe.

GLACIAL EROSION

In reference to the altitudes of the localities where folding has been noted: The disturbed strata of station 2 lie approximately 1,140 feet above sea-level. The area of disturbed strata north of Moravia lies within 1,080 and 1,160 feet altitude. Very diligent search at lower and higher ranges than these has not revealed any similar phenomena, but has, however, given much information on the subject of ice-erosion.

Fig. 4 is a photograph of a freshly uncovered rock surface about a mile and a half southwest of Moravia near the foot of the steep valley wall. The well-rounded angles, showing the polishing work of the ice as block after block of the thin bedded sandstone material has been removed, the general smoothing of the whole surface, the irregular gouges and the striae attest the vigor of ice-work here. Several similar areas were likewise noted; the one shown, however, is typical and different from the others only in revealing a larger surface. Here the average direction of the striae is S. 13° E., a direction that shows the control exercised by the valley. This surface has an altitude of about 790 feet, standing but slightly more than 50 feet above the inlet stream near the base of the valley wall. The slope of the polished surface has the general grade of the valley wall immediately above and below. While this surface is very illustrative of the corrasive work of ice, it is felt nevertheless that the processes of ice degradation which it represents are of the same type as have probably been effective in giving the valley cross-section its U-outline.

Directly west of Moravia at approximately the 900-foot contour is another area showing numerous striations which have an average direction of S. 37° E. The surface at this place is slightly steeper than that just noted. It also stands higher above the flood plain below.

East of Moravia near the forks in the highway leading up the hill is another area of very active ice-polishing. Its altitude is 830 to



FIG. 4.—Glaciated surface southwest of Moravia, N. Y.

860 feet. We note here, however, two sets of striae; the stronger measures S. 56° – 63° E. This set probably represents the general movement of the ice-sheet, modified perhaps slightly by local topography. The direction of the weaker set is S. 19° – 25° E. It should be noted that this surface stands at an angle in the Owasco Inlet valley. The north leg of this angle has approximately the direction of N. 32° W., and the south leg, S. 8° W. Leading into the major valley from the east a tributary valley enters at this point. The striated surface, however, is some 100 feet below the rock bottom of this tributary valley which in accordance with the recent literature would be called a “hanging valley.” It is possible, therefore, that

this relation of valleys here has tended to mollify the general effectiveness of ice-corrasion.

On the uplands striated surfaces again appear. These surfaces range from 1,200 to 1,400 feet in altitude, and even above this they are to be found on the salients opposed to the direction of ice-motion. Averages of several scores of readings made in different localities ranging between the 1,200- and 1,400-foot contours give S. 46°-48° E. The averages of striae on surfaces still higher give S. 53°-61° E. These areas fall within a reach of three miles of the major

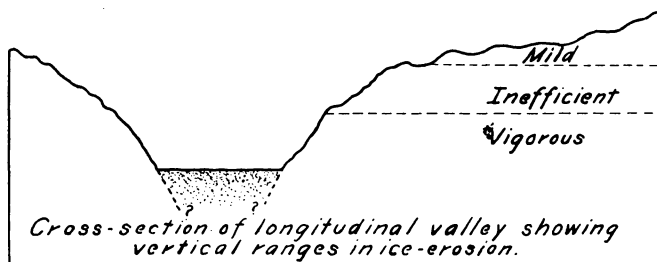


FIG. 5.

FIG. 5.—Cross-section of longitudinal valley showing vertical ranges in ice-erosion.

valley; in the main they are found in the general flat country constituting plateau divides.

Between the two zones of ice-erosion already mentioned, that is the areas near the bottom of the major valley and the areas on the uplands, lies another zone of least effective ice-work. This is the horizon of the folded subjacent strata; in the Owasco valley area it is approximately between the 1000- and 1200-foot contours.

Fig. 5 summarizes these observations. The cross-section is normal to the axis of the longitudinal valley, not taking note of the deflections of this axis. The matter of altitude in relation to sea-level is likewise neglected, as great discordance may exist between present-day and Wisconsin ice-epoch altitudes. So little is known definitely about the relation that existed, during Pleistocene time, between the land mass of northeastern North America and sea-level, and furthermore, the connection between ice-erosion and a base level from which altitude is measured, may probably be so slight, that this relation, as a factor, may safely be neglected. The topographic

aspect of the region of our cross section, however, is very important. In the uplands, or divide plateau areas, glaciated surfaces are found wherever the rock is not drift-covered. These striated surfaces attest considerable planing or abrasive work by the ice-sheet. As these flat elevated areas decline to the valleys we find a range of very subdued ice-work, the zone of disturbed subjacent strata, and of residual rock decay *in situ*. But proceeding down the valley slopes the evidence of ice-corrasion gradually increases. The strongest evidence so far noted in the field is found within a short distance vertically of the flood plain. We have then (Fig. 5) three ranges showing variation in the effectiveness of ice-erosion: (1) the range of mild erosion; (2) of inefficient erosion; and (3) of vigorous erosion.